

HIGH ORE CREEK WATERSHED RESTORATION

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ABSTRACT

A cooperative effort by the state of Montana, Bureau of Land Management, twenty private landowners, and several contractors resulted in the restoration of four miles of stream channel on High Ore Creek and the reclamation of the Comet, Golconda, King Cole, and Silver Hill mines in the High Ore Creek watershed. High Ore Creek, located east of the town of Basin in Jefferson County, Montana, flows through the abandoned Comet Mine and Mill site and into the Boulder River.

Mill tailings and waste rock, from about 400,000 tons of ore milled at the Comet Mine, filled a large area of the High Ore Creek Valley and were retained behind a dam. Failure of the dam allowed mine wastes to erode and be transported downstream to the Boulder River. The Montana Department of Environmental Quality, Mine Waste Cleanup Bureau (MWCB) completed the first phase of reclamation at the Comet mine site in the 1997 and 1998. Approximately 430,000 cubic yards of mine wastes were excavated and placed into the pit area. The Bureau of Land Management, in 1999 and 2000, and the MWCB, in 2001, removed streamside tailings material, a significant source of metal and sediment contamination in the High Ore Creek and Boulder River watersheds. Reclamation included the removal of approximately 62,000 cubic yards of streamside tailings and waste-rock over a 4-mile length of stream channel, stream channel and floodplain reconstruction, and re-vegetation with native plant species.

The Montana Bureau of Mines and Geology (MBMG) has been monitoring water quality in the High Ore Creek and Boulder River watersheds since 1997. The MBMG compared post-reclamation analytical results with pre-reclamation water-quality data to determine the success of the Comet Mine and High Ore Creek reclamation projects. Analytical results indicate trace-element concentrations are substantially lower than pre-reclamation conditions.

INTRODUCTION

High Ore Creek is located northwest of Boulder, Montana in Jefferson County, Montana. High Ore Creek flows through the Comet Mine site and into the Boulder River approximately 3-miles northeast of the town of Basin.

The Comet Mine and Millsite is one of the oldest abandoned hardrock mine sites in the Basin/Cataract Mining District. The site was first mined in about 1880 by the Alta-Montana Mining Company. The majority of the production from the Comet occurred from 1883 to 1893 while owned by the Helena Mine and Reduction Company. Initially, ore was rope trammed to a milling and smelting facility in the nearby town of Wickes, about 5 miles northeast of the mine. In

1889, a mill was built at the mine site to process ore from the Comet Mine; the mill tailings were placed in an impoundment located in the High Ore Creek flood plain. Unlike most mines that shut down in 1893 due to the silver panic, the Comet Mine continued operation through 1897. Between 1900 and 1926, the mine was worked by several different operators; a 3-compartment shaft was sunk to a depth of 975 feet, and levels were driven at 100-ft intervals down to the 800 level; and most of the ore was removed from the 100 and 200 levels. The mine consists of 9 drifts at levels comprising 20,000 feet of lineal workings. The Basin Montana Tunnel Company acquired the Comet in 1926 and constructed a new 200-tons per day flotation mill in 1931 to treat ore from the Comet and Grey Eagle mines. Interestingly, the mill tailings from the previous operations were reprocessed through the new mill and \$1.4 million of metals recovered.

The Comet Mine is credited with production valued at \$13,000,000 prior to 1911. From 1934 through 1940, production from the Comet Mine averaged about 58,000 tons per year. The Comet and the Grey Eagle mines closed in 1941. Reported production for the Comet Mine from 1904 to 1950 is 493,444 tons of ore, which yielded 41,754 ounces of gold, 3,152,896 ounces of silver, 28,222,300 pounds of lead, 23,835,847 pounds of zinc, and 2,234,353 pounds of copper.

ABANDONED MINE LAND RECLAMATION, MONTANA

Cooperating state and federal agencies using a collaborative “watershed approach” identified the Boulder River as a priority watershed to begin reclamation of AML sites impacting water quality in 1997. The Montana Department of Environmental Quality, Mine Waste Cleanup Bureau (DEQ), administers the abandoned mine land (AML) program for the state of Montana using funds from the Office of Surface Mining to reclaim private lands impacted by historic mining. The U.S. Bureau of Land Management, Butte Field Office, (BLM) is responsible for the reclamation/remediation of all AML sites on BLM administered lands in Montana. The BLM identified the Boulder River as one of the two pilot watersheds that would be used to implement a watershed approach for reclamation of AML sites impacting water quality. Funding for restoration of High Ore Creek, a tributary of the Boulder River, was provided as part of the Clinton administration’s Clean Water Action Plan.

The Comet Mine and High Ore Creek Stream Side Tailings Reclamation projects were considered non-time critical removal actions under the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). In accordance with the NCP, an Expanded Engineering Evaluation/Cost Analysis (EEE/CA) for the Comet Mine and High Ore Creek Stream Side Tailings Reclamation Projects were completed and used to present the detailed analysis of reclamation alternatives. The detailed analysis of alternatives and additional background information provided in each EEE/CA was used to determine the preferred alternative for reclamation at the Comet Mine and High Ore Creek.

The Montana Department of Environmental Quality inventoried the Comet Mine in 1993 for inclusion on the Abandoned Hardrock Mine Priority List (DEQ/MWCB-Pioneer Technical Services, Inc., 1995). The Comet scored 10th out of 276 sites using the Abandoned and Inactive Mines Scoring System (AIMSS). The Montana Bureau of Mines and Geology (MBMG) inventoried abandoned mines in the High Ore Creek watershed in cooperation with the Bureau of Land Management (MBMG, 1995). Most of the sites inventoried consisted of caved adits with

small unvegetated waste dumps. Environmental problems associated with these sites were mostly due to waste material being entrained in storm water and transported to High Ore Creek. Mine waste and mill tailings at the Comet Mine and Mill, and stream side tailings along the lower 4-mile reach of High Ore Creek were identified as the most significant environmental problem affecting Bureau of Land Management administered land in the High Ore Creek drainage

WATERSHED RESTORATION

Initial reclamation work began at the mine and mill site in 1990 when the Montana Department of Fish, Wildlife, and Parks (FW&P) reconstructed a pre-existing creek diversion around the tailings impoundment. The Montana FW&P also reconstructed an existing sedimentation pond to capture storm water running off from the tailings and control the release of mine waste sediments into High Ore Creek.

The MWCB conducted interim reclamation activities at the mill site in 1995 and 1996 to improve erosion and sediment control from the tailings in preparation for full-scale reclamation of the site (DEQ/MWCB-Pioneer Technical Services, Inc., 1996). The MWCB initiated Phase I of the Comet Mine and Mill Site reclamation in 1997. Phase I of the Comet Mine and Mill Site reclamation required the construction of a mine waste repository at the location of the abandoned glory hole. Approximately 300,000 cubic yards of waste rock and tailings were removed from the flood plain and placed in a constructed repository at the Comet Mine site.

The Bureau of Land Management's High Ore Creek stream side tailings reclamation portion of the watershed restoration began in 1999 and was completed in 2000. The stream side tailings reclamation began below the Comet Mine site and continued to the creek's confluence with the Boulder River. The stream side tailings reclamation included approximately 32,000 cubic yards of stream side tailings and 5,800 cubic yards of waste rock that was distributed throughout the 4-mile High Ore Creek flood plain below the Comet Mine.

The MWCB completed Phase II of the Comet Mine reclamation in 2001. This reclamation involved removal of approximately 39,000 cubic yards of tailings and waste-rock material beneath the High Ore Creek diversion channel and placement of these materials into the BLM repository located 1-mile SE of the Comet Mine. The diversion channel installed in 1990 was removed and the High Ore Creek stream channel was reconstructed and returned to its original location in the bottom of the valley. The Comet Mine and BLM repositories were capped with soil and seeded.

OBJECTIVE

The objective of the Comet Mine and Millsite Phase I and Phase II Reclamation Projects were to protect human health and the environment in accordance with the guidelines set forth by the NCP. Specifically, the remedy was selected to limit human and environmental exposure to the contaminants of concern and reduce the mobility of those contaminants in the local surface water and groundwater resources, and to reduce the safety hazards associated with an open shaft at the site.

The objective of reclamation in the High Ore Creek watershed was to reduce the detrimental impacts to water quality and riparian vegetation as well as the impacts to human

health and the environment. Reclamation was expected to restore riparian vegetation; allow High Ore Creek to function properly; improve water quality; and potentially establish a healthy, diverse biotic community and fisheries. The High Ore Creek reclamation is expected to bring the BLM into compliance with the requirements of the NCP, the Butte Field Office's RMP/EIS, and the Clean Water Act.

COMET MINE AND MILL SITE RECLAMATION

The Comet Mine and Millsite is located in the northeastern part of the Basin/Cataract Mining District. The legal description of the site is South 1/2 of Section 36, Township 7 North, Range 5 West. The Comet site is located adjacent to High Ore Creek on privately owned land, and is bordered by BLM-administered land. The altitude ranges between 6,100 and 6,400 feet above mean sea level. The terrain surrounding the site is generally rugged and consists of relatively steep south and north facing slopes. The climate of the area, typical of southwest Montana, is cool and dry. Average annual precipitation at Basin is about 14 inches; temperature records for Boulder, 5 miles to the southeast, indicate average maximum high temperatures of about 80°F in July and August, and average minimum temperature of 9°F in January (Western Region Climate Center, 2001).

The Comet Mine site encompasses an area of approximately 35 acres, and includes two tailings impoundments located in the High Ore Creek flood plain, three waste rock piles (two of which are in the flood plain), five waste-rock dumps on Silver Hill, a large glory hole or open pit mine area, and numerous abandoned buildings and structures associated with the mine and the town of Comet. The mill-tailings deposits have been eroding into the creek for many years.

General problems at the Comet Mine site that could impact human health included high concentrations of metals and arsenic in waste materials (mill tailings and waste rock), and elevated concentrations of metals and arsenic in surface water, and stream sediments downgradient from the site. The easily accessible waste materials may result in significant health-related consequences to the human population. At the Comet site, mill tailings, underlying soils, waste rock piles, surface water, and stream sediments had arsenic, silver, cadmium, copper, iron, mercury, lead, antimony, and zinc present at concentrations significantly above background levels.

INTERIM RECLAMATION ACTION

During the spring of 1996, the DEQ conducted the Comet Mine Interim Reclamation Project. The objective of this interim project was twofold: first, the sediment control capabilities of the existing sediment pond needed to be returned to a functional condition; and second, construction of a lower sediment pond to improve the sediment trapping capabilities and serve as the first phase of the overall site-reclamation strategy. As part of this interim action, a new sedimentation pond was constructed; approximately 2,500 cubic yards of sediment were removed from the existing sedimentation pond constructed in 1990; a temporary fence was erected around the sedimentation ponds; and temporary erosion controls were installed within the tailings impoundment areas.

Under contract with the DEQ's AML program, Pioneer Technical Services, Inc., was assigned the responsibility of engineering and preparing the interim reclamation specifications prior to contractor selection, and conducted on-site quality assurance inspections during construction. Smith Contracting, Inc, from Whitehall, Montana, performed the work for the Comet Interim Construction Project. Total construction cost for the interim reclamation action was \$46,905. The total engineering cost for this project was \$45,701. The Work Plan, Field Sampling Plan and Reclamation Investigation cost \$21,156 to prepare. Construction engineering and preparation of plans and specifications cost \$12,893. Construction management including engineering administration and inspection cost \$11,651.

PHASE I RECLAMATION ACTION

The Phase I reclamation activities at the Comet Mine and Millsite took place during the 1997 construction season (September through December) and the 1998 construction season (May through July). Pioneer Technical Services, Inc. (under contract with the DEQ/MWCB), was responsible for preparing the final design and engineering specifications for the project, and for overseeing construction. Ten qualified bidders responded with bids ranging from \$903,580 to \$1,989,639. The Engineer's estimate was \$1,943,650 for the project. The contract was awarded to the lowest qualified bidder, Shumaker Trucking and Excavating Contractors, Inc. Shumaker performed all of the on-site construction work.

The project involved consolidating the solid media waste sources which represented the greatest risks to human health and the environment (two tailing impoundments located in the High Ore Creek flood plain and several waste rock dumps) into an open pit located at the site. The pit was divided into an upper and lower section. The lower pit contained most of the coarse waste rock and was constructed as a buttress to contain the wetter, finer-grained tailings that were placed in the upper pit. Most of the excavated areas were graded to blend into the native contours. After the specified wastes were placed into the open pit, the entire contents of a larger waste-rock dump material were placed over the wastes to act as an interim cover until the final cap was installed.

The purpose of the Phase I Comet Mine Reclamation project was to excavate two tailings ponds and three waste rock dumps and disposed of them in the open pit located on the east side of the site. The wet tailings were to be disposed within the deepest portion of the pit, and the dry tailings and waste rock were disposed of in the open section of pit and the benched area within the pit. Sediments contained in the upper settling pond were completely excavated and disposed of in the open pit. A portion of the High Ore Creek diversion embankment was also excavated and disposed of in the pit.

Phase I of the project was completed over two construction seasons. The most significant items completed during Phase I construction included the excavation and consolidation of 300,000 cubic yards of tailings and waste rock materials; and revegetation of 15 acres of reclaimed land. The construction cost for the Comet Mine and Millsite Phase I project was \$1,268,624. Shumaker's original bid of \$903,580 was increased by \$365,043 due to quantity increases and change orders. The total engineering costs associated with the project were \$296,967.

During Phase I of the Comet Mine Reclamation Project most of the contaminant sources, responsible for impacting the High Ore Creek drainage were removed from the site. The largest waste rock dump was removed and the area recontoured to its slope; compost, fertilizer, seed, and erosion control mat were added to the slope.

After the Comet Mine and Millsite Phase I Reclamation Project was completed, the Comet Mine repository was monitored for a year due to several large cracks and seeps which had developed over and along the repository face. The monitoring indicated that the repository was settling, rather than failing. It was also determined that the Comet repository was filled to capacity, and that an alternative repository site was necessary to dispose of the remaining mine wastes. Prior to Phase II reclamation, the BLM and the DEQ entered into a cooperative agreement allowing the DEQ to place the remaining mine wastes into an engineered, multi-layered repository situated on BLM administered land. In addition, the BLM provided approximately 35,000 cubic yards of borrow material to be used as cover soil/topsoil for the Comet Mine site.

PHASE II RECLAMATION ACTION

The purpose of the Comet Mine and Millsite Phase II Reclamation Project was to remove the remaining mine waste from the site, restore the High Ore Creek valley through the Comet Minesite, cap the Comet and High Ore Creek repositories with engineered, multi-layered caps, revegetate the Comet Mine site, and to fence the reclaimed areas to allow for vegetative growth to become established. All construction activities for the Comet Mine and Millsite Phase II Reclamation Project occurred during the 2001 construction season. The reclaimed mine site was completely fenced during the spring of 2002. Olympus Technical Services, Inc. (Helena, Montana) was assigned the responsibility of engineering and preparing the reclamation specifications for the Comet Mine Site. Olympus was also responsible for construction engineering and quality control inspection for the Comet Mine Site. Pioneer Technical Services, Inc. was responsible for the engineering, preparation of the reclamation specifications, and the construction engineering and quality control inspection for the BLM repository site. Two qualified bidders responded with bids ranging from \$1,317,417 to \$1,638,597, with an average of \$1,478,007. The Engineer's estimate was \$967,717. Mobilization was unintentionally left blank on Shumaker's original bid submittal. One subcontractor was used for fence installation on the project.

Phase II reclamation involved the removal of residual tailings from the High Ore Creek flood plain area, and the removal, replacement, and grading of 23,196 cubic yards of non-tailings overburden soil to access tailings for excavation and disposal in an engineered repository designed and constructed by the BLM and U.S. Army Corps of Engineers. The work involved construction of 1,491 lineal feet of High Ore Creek stream channel through the former Comet Mine tailings and waste rock pile area. The majority of the 39,206 cubic yards of tailings were placed and compacted in the BLM repository. The remaining tailings were placed on top of the Comet Mine repository. A temporary bridge was installed to cross the stream reconstruction area and provide access to the Comet repository, BLM repository and cover soil stockpile. The stream channel construction involved excavation of the streambed and banks, placement of streambed backfill material, and the installation of erosion control mat and willow cuttings on the

streambanks. A drop structure was constructed to convey High Ore Creek into the constructed stream channel. The existing High Ore Creek riprap-lined diversion channel and gabion drop structure (constructed in 1990 by the Montana Department of Fish, Wildlife, and Parks) were removed. Waste rock piles, slopes and depressions in the vicinity of the Comet Millsite and the Silver Hill area were graded, contoured, amended with fertilizer and compost, and revegetated.

An open shaft on the Comet Mine repository buttress slope, as well as a shaft near the Silver Hill area that was discovered during construction, were backfilled. Approximately 35,000 cubic yards of cover soil was applied and graded on the repository buttress slope and the slope was graded with dozer basins for erosion control. The repository buttress slope, graded flood plain, and graded waste rock areas were amended with 1,258 tons of organic compost and revegetated with native plant species. The Comet and BLM repositories were capped with geocomposite clay liners and organic amended cover soil. Other work items included removal and on-site disposal of debris, construction of a runoff control ditches, repair and grading of a slump area, and reclaiming the access road through the site. The project site was fenced off with a 4-strand barbed wire fence to control access in order to establish vegetation.

Shumaker Trucking and Excavating Contractors was awarded the contract and the construction cost for the Comet Mine and Millsite Phase II project was \$1,581,899.75. The original bid was \$1,317,430.00 for the Comet Mine and Millsite Phase II project, with three change orders issued. The major cost items were tailings excavation, hauling, placement, grading and compaction (11.9%), organic amendment (8.65%), mobilization (6.88%). The total engineering cost for this project was \$161,572.04. The total project cost was \$1,743,471.79.

HIGH ORE CREEK STREAM SIDE TAILINGS RECLAMATION

The High Ore Creek watershed consist of an 8.5-square mile area. Forty-three percent of the lands on High Ore Creek are Public Lands administered BLM and 57% of the land is private property belonging to 20 landowners with 34 patented mining claims. Nine County, State, and Federal Agencies along with numerous consultants, contractors and interested parties worked together to investigate, characterize, design, and mitigate environmental impacts on High Ore Creek.

Stream side tailings deposits from the Comet Mine and mill site (Figure 1) eroded into High Ore Creek for many years. Stream side tailings from the tailings impoundment located in the bottom of the drainage were released during large runoff events. Tailings were transported

downstream where they were deposited in the Creek and along the flood plane or flowed into the Boulder River. The most significant event occurred when the tailings-impoundment dam was breached by flood waters. This and subsequent events easily scoured the tailings and transported them downstream. In some downstream areas, tailings accumulations were several feet thick and spanned the width of the valley, typically a few hundred feet wide. In most of the areas along High Ore Creek, the tailings were less than 1 foot thick



Figure 1-Comet Mine prior to Phase I reclamation.

These tailings were the largest mine waste source of concern because they are one of the highest contributors of metals and sediment to the surface water. These tailings severely affected the vegetation in the flood plain of High Ore Creek.

The Montana Bureau of Mines and Geology (MBMG, 1995) and the BLM (BLM, 1999) measured concentrations of antimony, arsenic, cadmium, copper, iron, lead, manganese, silver, and zinc that were significantly elevated above background concentrations ($>3X$) in soil and water samples in the flood plain and surrounding area. Preliminary findings by the U.S. Geological Survey also indicate that sediments, fluvial tailings and water from High Ore Creek are significant contributors to water quality degradation of the Boulder River below Basin, Montana (USGS, 1999). In 1998 the BLM initiated the reclamation of High Ore Creek with the development of the Expanded Engineering Evaluation/Cost Analysis (EEE/CA) to evaluate reclamation alternatives.

SITE ASSESSMENT

Site assessment began with the initiation of the EEE/CA in February 1998. Site assessment, in addition to the EEE/CA, included: 1) Owner/Operator History Report, 2) Community Relations Plan, 3) Quality Assurance Project Plan, 4) Laboratory Analytical Protocol, 5) Health and Safety Plan, 6) Cultural Inventory Report, and 7) Engineering Design/Construction Bid Specification Package.

The stream side tailings were the largest mine-waste source of concern because of high contributions of metals and sediment to the surface water. Reclamation first required the identification of mine waste types, location, volumes, and impacts to human health and the environment. The BLM conducted a stream inventory on High Ore Creek in 1998 to identify stream reach segments that required reclamation. Twenty-one reaches with 45 sub-reaches were identified that required reclamation as a result of mining impacts or poorly functioning riparian areas. The stream side tailings were separated into three types of tailings impacted areas. Areas

with no vegetation growing on the tailings (approximately 21 acres) were classified as High Impact Areas (Figure 2). Areas where tailings were visible with some vegetation were classified as Medium Impact Areas (Figure 3). All remaining areas of the High Ore Creek flood plain were considered Low Impact Areas. Vegetation was prominent in these areas with little or no effect from the tailings. Some Low Impact Areas required stream bank reconstruction to return riparian areas to a functioning condition. Discrete and composite samples, from separate sampling events, in the High Ore Creek flood plain were collected by Pioneer Technical Services Inc., the MBMG, and the BLM. Thirty-seven discrete samples and one composite sample were collected for X-ray Fluorescence Spectrometer (XRF) analysis, while three composite samples were collected for analysis of total metals, Acid Base Accounting (ABA), agronomic and Toxicity Characteristic Leaching Procedure.



Figure2 - High Impact Areas.



Figure 3 - Medium Impact Areas.

Risk Assessment

Stream side tailings were separated into three types of tailings impacted areas to assist with the analysis of alternatives based on the following criteria: 1) the relative protectiveness of human health and the environment provided by the alternatives; 2) the long-term effectiveness provided by the alternatives; and 3) the estimated attainment of ARARs for each alternative. An alternative screening summary, Table 1, was used to determine alternatives retained for detailed analysis. Table 2 is a summary of overall cost comparisons between the Alternatives based on the amount of Human Health (HH) and Ecological Risk Reduction (E).

Table 1. Alternatives Screening Summary (BLM, 1999).

ALTERNATIVE DESCRIPTION	EFFECTIVE- NESS	IMPLEMENT- ABLE	EST. COST	RETAINED FOR DETAILED ANALYSIS
Alt. 1: No Action	NA	NA	\$0	Yes
Alt. 2: Institutional Controls	Low	Yes	\$390,000	No
Alt. 3: In-Place Containment of Wastes With Cover soil	Low-Medium	Yes	\$674,298	No
Alt. 4a: Partial Removal/Disposal in Constructed Repository and Partial In-Place Containment (bottom liner and drainage layer)	High	Yes	\$1,139,602	Yes
Alt. 4b: Partial Removal/Disposal in Constructed Repository and Partial In-Place Containment (no bottom liner)	High	Yes	\$1,020,211	Yes
Alt. 5a: Removal/Disposal of all Solid Waste Material in a Constructed Repository (bottom liner and drainage layer)	High	Yes	\$1,529,393	Yes
Alt. 5b: Removal/Disposal of all Solid Waste Material in a Constructed Repository (no bottom liner)	High	Yes	\$1,343,786	Yes

Table 2. Alternative Cost-Effectiveness Comparison Summary (BLM, 1999)

ALTERNATIVE	Ecologic Risk Reduction (E)	Human Health Risk Reduction (HH)	Total Present Worth Value	Cost per 1% Reduction in Risk (\$)
Alternative 1	0%	0%	\$1.14 Million	NA
Alternative 4a	72%	94%	\$1.02 Million	\$15,833 (E) \$12,128 (EH)
Alternative 4b	72%	94%	\$1.02 Million	\$14,167 (E) \$10,851 (HH)
Alternative 5a	76%	100%	\$1. 53 Million	\$20,132 (E) \$15,300 (HH)
Alternative 5b	76%	100%	\$1.53 Million	\$17,632 (E) \$13,400 (HH)

Alternative 4b was selected as the preferred alternative for the reclamation of High Ore Creek. This alternative should protect human health and the environment by removing the highest risk mine wastes in the High Ore Creek watershed. This alternative consists of excavating selected solid waste material from the High Ore Creek flood plain and disposing of it in a modified RCRA repository constructed about 1 mile southeast of the Comet Mine site. The repository design includes a multi-layered cap with no bottom liner. This alternative is expected to reduce risks to human health by 94% and ecological risks by 72%. The long-term effectiveness of this alternative is expected to improve the water quality protect human health and the environment.

RECLAMATION

The construction bid package for reclamation was administered for the BLM by the U.S. Army Corp of Engineers (USACE) and contained the reclamation engineering design, project plans and specifications prepared by Pioneer Technical Services, Inc.. Schumaker Trucking and Excavating Contractors, Inc., from Great Falls, MT, was awarded the construction contract and issued a Notice to Proceed by the USACE in September 1999. Shumaker Trucking and Excavating Contractors, Inc. began construction in September, 1999 and completed construction in June, 2000.

The reclamation of High Ore Creek included: areas with complete tailings removal, channel, and flood plain reconstruction; areas with partial tailings removal and flood plain reconstruction; areas with only stream bank reconstruction ; and areas with no tailings removal or stream bank reconstruction. The construction contract involved removing waste adjacent to High Ore Creek and disposing of these materials in a constructed repository located approximately 1 mile southeast of the Comet Mine and Mill site.

Reclamation included:

- Clearing, grubbing, and constructing a six acre borrow area/repository and improving the existing access road to the repository,
- Stockpiling 34,000 cubic yards of cover soil to be used by the MWCB for Phase 2 of the Comet Mine reclamation,
- Excavating and hauling 31,913 cubic yards of stream side tailings and mine wastes to the BLM repository,
- Installing 4,127 lineal feet of stream protection structures,
- Installing 12,246 lineal feet of silt fence,
- Reconstructing 3,459 lineal feet of High Ore Creek stream channel,
- Reconstructing flood plain with 14,276 cubic yards of clean cover soil,
- Backfilling flood plain with 18,103 cubic yards of clean, organically amended cover soil (topsoil) following waste removal,
- Constructing streambed including steps, pools, and grade control structures,
- Installing 4,612 square yards of Type A bank stabilization fabric,
- Installing 8,442 square yards of Type B erosion control mat,
- Installing willow cuttings and 833 lineal feet of willow fascines on stream banks, and

- Seeding and mulching reconstructed and stabilized streambanks.
- Construction of the repository cap:
 1. Installation of 17,531 square yards of a geotextile cushion over the uppermost lift of compacted mine wastes,
 2. Installation of 18,051 square yards of Geosynthetic Clay Liner,
 3. Installation of 17,811 square yards of a Geonoet and filter fabric geocomposite,
 4. Apply and grade 12,934 cubic yards of organically amended cover soil,
 5. Apply and grade 7.2 acres of salvaged topsoil, and
 6. Seed and mulch 7.2 acres.
- Construction of repository run-on/runoff control ditches,
- Replace and install four properly sized culverts on High Ore Creek,
- Obliterating and reseeded temporary haul roads and the existing access road between the Comet repository and the new BLM repository.

WATER QUALITY INFORMATION

Base flow in High Ore Creek at a monitoring station about 1-mile upstream from the confluence with the Boulder river is about 0.5 cfs. Peak flow measured in April 2002 at the same station was about 6 cfs. During the 2001 field season, peak storm flows caused by summer thunderstorms and fall rain and snowmelt runoff did not exceed 2 cfs.

Mineralization at the Comet is hosted by quartz monzonite and andesite. The zone of mineralization is nearly 150 feet wide, strikes almost east-west, and dips steeply south to vertical. The ore consist of galena, sphalerite, and pyrite with some arsenopyrite, chalcopyrite, and tetrahedrite in a gangue of quartz, carbonate minerals, and altered wallrock. Average ore concentration include 0.084 ounces gold and 6.4 ounces silver per ton, 3.2 % lead, 3.9 % zinc, and 2.2 % copper (Roby et al., 1960; Becraft et al., 1963).

Laboratory analyses for water samples collected at 8 stations along High Ore Creek and tributaries as part of the initial abandoned-mine inventory and two diurnal sampling events at one station were used for the pre-reclamation basis. These pre-reclamation samples were collected during low stream flow when storm water was not flowing into the creek. For the post-reclamation monitoring, water samples were collected at selected sites as a way to assess the effectiveness of reclamation; as a way to assess the three different reclamation approaches; and as a way to identify any stream reaches or sites that may require additional work. Current monitoring includes collecting water samples for laboratory analyses and/or field parameters at 8 stations during low-flow; and diurnal sampling at the same station that was sampled during the pre-reclamation monitoring (Figure 4).

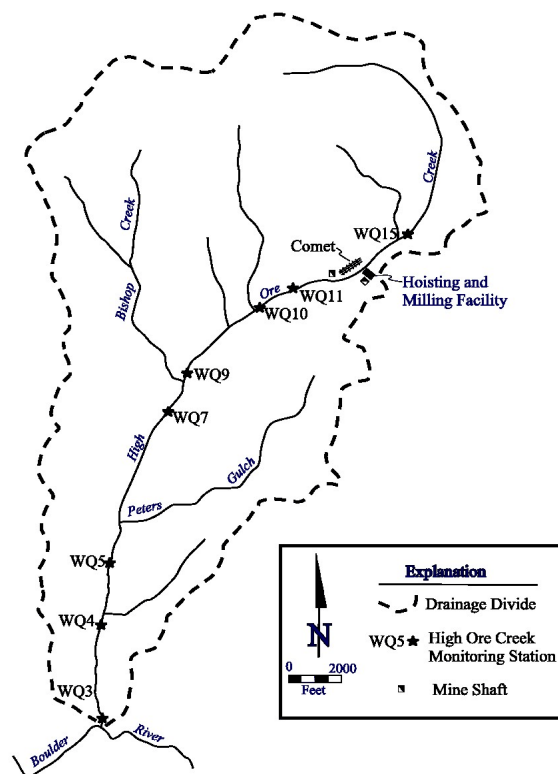


Figure 4. High Ore miles east of Basin, are monitored along High Ore Creek and its tributaries for field parameters and/or major ions and trace element constituents.

Creek is located about 4-Montana. About 8 stations

At each monitoring station, stream flow was measured with a current meter, parshall flume, or pipe-bucket-stopwatch; and field parameters including pH, dissolved oxygen, specific conductance, and temperature were measured with field instruments. During low-flow, samples were collected for dissolved analyses of major anions, major cations, trace element and for total-recoverable analyses of major cations and trace elements.

RESULTS

Most pre- and post-reclamation field parameters values were similar. High Ore Creek field parameters were monitored continuously with a data sonde. The most significant and important change in field parameters was pH. Prior to reclamation, pH in High Ore Creek was about 7.7 and varied by a few tenths of a pH unit due to diurnal fluctuations caused by photosynthesis and respiration of aquatic organisms. Post reclamation monitoring indicates that pH is now about 8.7 and also varies diurnally. Typically, pH is highest in late afternoon, and lowest in early morning. Dissolved oxygen fluctuates diurnally, but is at or near saturation---about

9.5 mg/L---during daylight hours. Temperature can vary significantly in a 24-hour period; during July and August, early morning water temperature is about 10EC, and late afternoon temperature is about 20EC. Pre-reclamation and post-reclamation specific conductance values of High Ore Creek were about 360 mS/cm.

Low-Flow Sampling. Table 3 compares pre-and post-reclamation concentrations of selected trace element constituents at monitoring station WQ3, just upstream from the mouth of High Ore Creek. With the exception of arsenic, post reclamation concentrations of most trace elements were below pre-reclamation concentrations; the post-reclamation concentration of arsenic was higher than the pre-reclamation levels.

Table 3. Pre- and post-reclamation dissolved concentrations of selected trace elements at WQ3, near the mouth of High Ore Creek.

	Date	Fe (mg/L)	Mn (mg/L)	Ag (ug/L)	As (ug/L)	Cd (ug/L)	Cu (ug/L)	Pb (ug/L)	Zn (ug/L)
Pre	9/28/1993	0.107	0.814	<1	18.9	5.6	5.1	<2	1970
Post	10/17/2000	<0.024	0.199	<1	21.5	<2	2.51	<2	807

Figures 5a through 5e compare pre- and post-reclamation loading rates for dissolved cadmium, iron, manganese, and zinc collected in October 2000, and in September 1993 at monitoring stations along High Ore Creek. Loading was calculated by multiplying flow rates by concentrations, and is reported in units of g/day (Tupling, 2001).

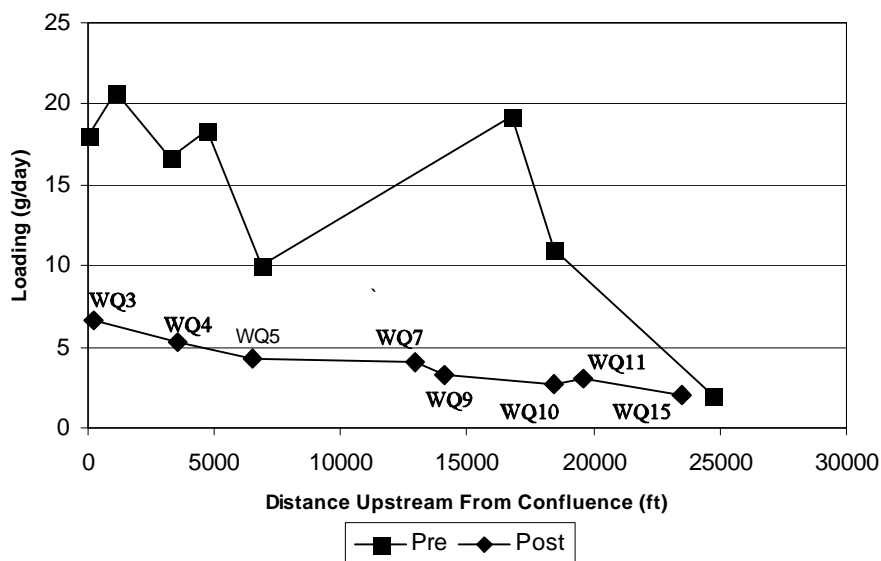


Figure 5a - Cadmium

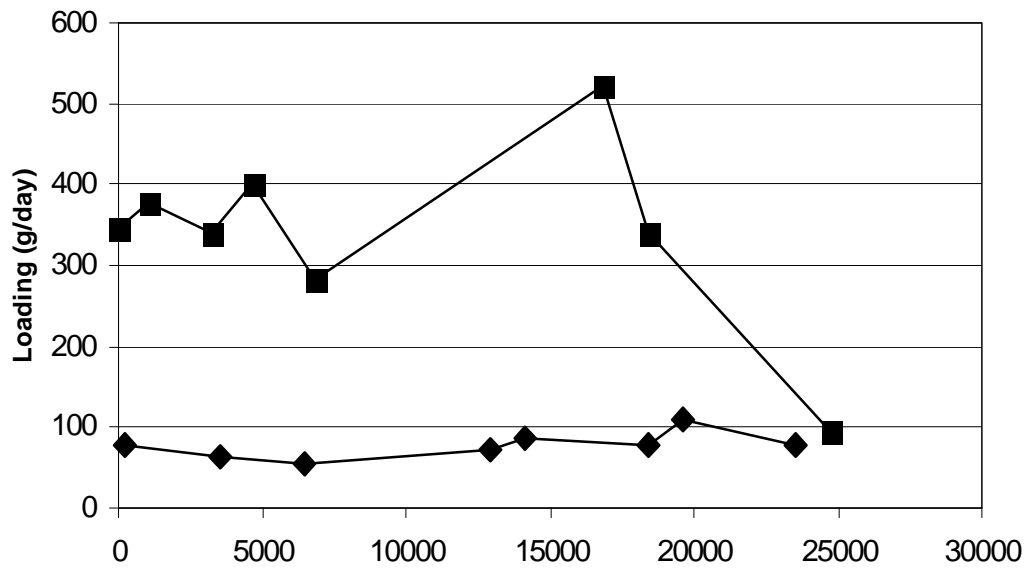


Figure 5b - Iron

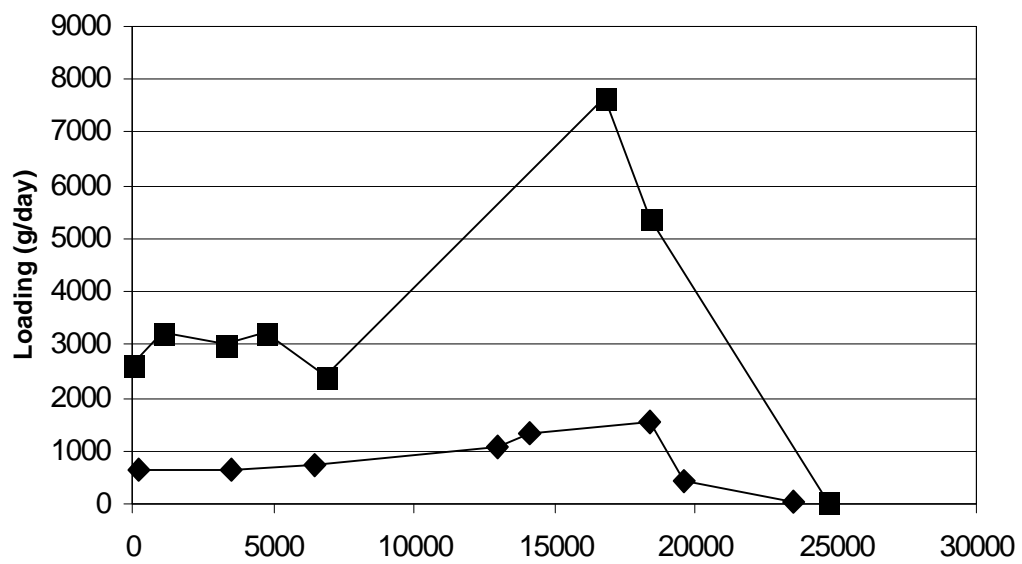


Figure 5c - Manganese

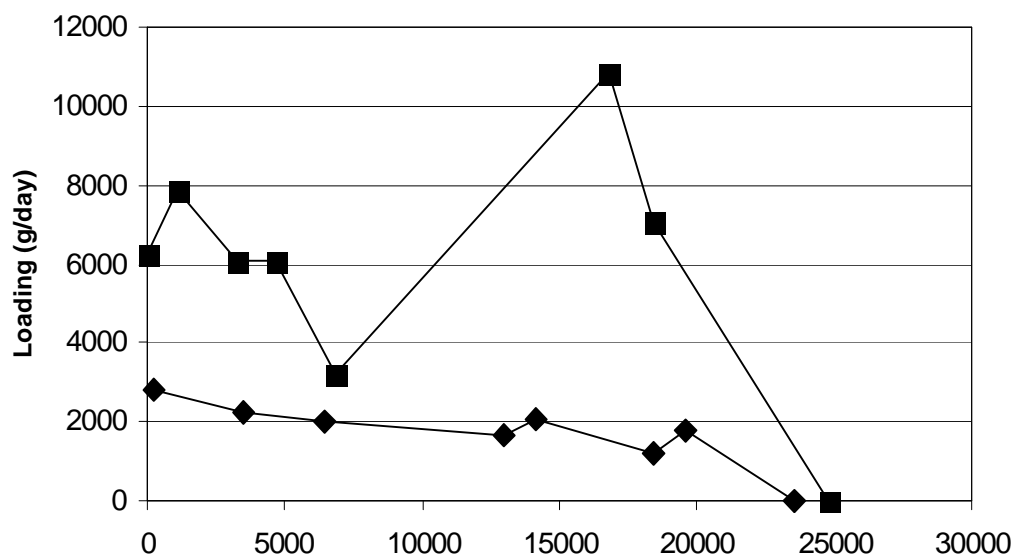


Figure 5d - Zinc

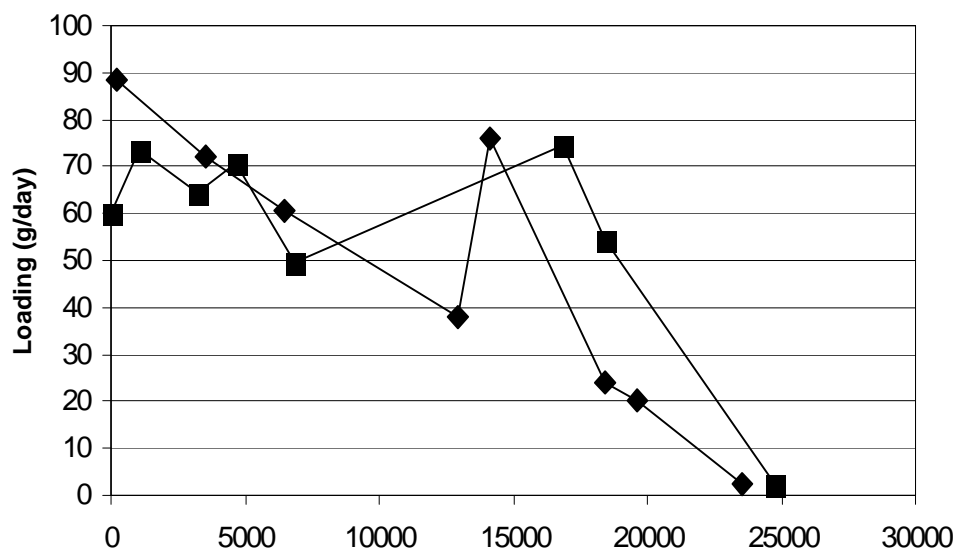


Figure 5e - Arsenic

Figure 5a-e. Post reclamation loading at the mouth of High Ore Creek (WQ3) has decreased significantly for cadmium, iron, manganese, and zinc. Post reclamation loading of arsenic has increased slightly.

Data presented in Figures 5a through 5d clearly show that dissolved loading for cadmium, iron, manganese, and zinc have significantly decreased. During low flow, dissolved and total recoverable concentrations were essentially the same. At the mouth of High Ore Creek, the loadings from these constituents were approximately one third of the pre-reclamation values. In addition, removal of large quantities of mine waste from the flood plain has resulted in flatter loading profiles.

Figure 5e shows that post reclamation arsenic loading has increased between 1993 and 2000. Removing the stream side tailing along the flood plain of High Ore Creek undoubtedly decreased the acid generation and acid contribution to High Ore Creek, which may explain why the post-reclamation pH is almost a log unit greater than pre-reclamation pH. Increased pH in High Ore Creek would tend to increase instream arsenate mobility. Because phosphate is more selective than arsenate for exchange sites, phosphate in the fertilizer may have replaced arsenate on adsorption sites, thus mobilizing arsenate (Darland and InsKeep, 1997).

Diurnal Cycling of Trace Elements. Pre-reclamation water samples for dissolved analyses of major cation, major anions, and trace elements were collected at station WQ4 at two-hour intervals from 12:25pm on the 26th August 1997 to 12:00pm on the 27th August 1997. Post reclamation water samples for dissolved analyses of major cations, major anions, and trace elements were collected at station WQ4 at two-hour intervals from 11:30am on the 24th July 2000 to 11:45am on the 25th July 2002. During both diurnal sampling events, trace elements that showed diurnal variations in concentration include Cd, Cu, Fe, Mn, Pb, Ti and Zn.

During the 2000 diurnal sampling event the changes in concentrations of the following trace elements were noted: Cd (max 2.8 Fg/L, min 2.1 Fg/L), Cu (max 2.9 Fg/L, min 2.0 Fg/L), Fe (max 216 Fg/L, min 88 Fg/L) Mn (max 113 Fg/L, min 60 Fg/L) Pb (max 7.5 Fg/L, min 2.9 Fg/L), Ti (max 8.3 Fg/L, min 2.8 Fg/L) and Zn (max 618 Fg/L, min 332 Fg/L). Maximum concentrations, for elements exhibiting diurnal cycling, occurred around the mid morning hours (06:00-10:00) with minimum concentrations occurring during the early evening hours (14:00-18:00).

Prior to reclamation, the concentration of zinc at station WQ4 would vary by as much as a factor of 5; maximum concentration of Zn during the diurnal sampling event in 1997 was 2570 Fg/L, and minimum concentration was 509 Fg/L. Figure 6 shows pre- and post-reclamation diurnal cycling of zinc in High Ore Creek.

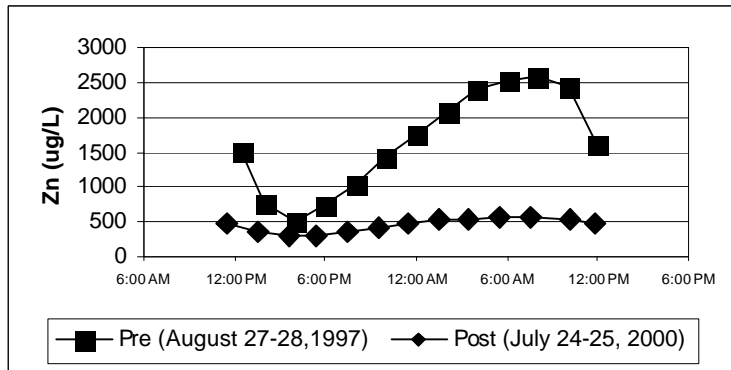


Figure 6. Dissolved zinc concentration in High Ore Creek fluctuates diurnally, but the fluctuations were more pronounced prior to reclamation with the concentrations varying by as much as a factor of five within a 24-hour period. Post-reclamation zinc concentrations fluctuate by a factor of about 1.5 within a 24-hour period; post reclamation zinc concentration is significantly lower than pre-reclamation values. Data from monitoring station WQ4.

SUMMARY

The areas targeted for reclamation at the Comet Mine and Millsite have been reclaimed and the hazards associated with the site have been mitigated. Total costs to reclaim the Comet Mine and Millsite were \$3,401,669. Of these expenses, \$2,897,429 was for construction, while \$504,240.45 was for engineering activities. The total construction contract, excluding engineering activities, for the High Ore Creek stream side tailings reclamation was \$1,520,837.

The necessity to completely remove all tailings rather than partial removal of tailings can not be adequately assessed until post reclamation monitoring results have been assessed as a part of the water quality monitoring program for this watershed. Pre and post reclamation changes in vegetation (Figures 7-8) and preliminary water quality results indicate reclamation of the Comet Mine and High Ore Creek watershed has been successful. Water quality and re-establishment of vegetation will be closely monitored for the next 3-5 years to determine the success of this reclamation project.



Figure 7-Pre-reclamation, 1997.



Figure 8- Post-reclamation 2000.

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